NATIONAL SCIENTIFIC BALLOON FACILITY
RECOMMENDATIONS FOR GONDOLA DESIGN
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INTRODUCTION

The experimenter using scientific balloons has unusual freedom to design and modify the flight vehicle which houses the experiment. This flexibility has resulted in highly creative solutions to design problems. However, because there is little documentation of appropriate design techniques, considerable time and money is often spent redesigning a gondola after its first few flights.

Presently, the National Scientific Balloon Facility (NSBF) requires mechanical certification of all gondolas, but the certification criteria are only minimum design standards which ensure that the gondola can withstand normal flight conditions. This recommendation establishes some very general guidelines for gondola design and points out common design problems which are peculiar to ballooning.

The NSBF and National Aeronautics and Space Administration/ Wallops Flight Facility (NASA/WFF) are conducting a study to better define the loads to which the gondola is exposed during flight. This basic recommendation will evolve as design experience accumulates from this work.

These guidelines will be most helpful during the early gondola development stage when critical design decisions are being made. Initial design development is especially important because it can impose restrictions on the experiment that only become evident as the plan matures. Well before a design is finalized, the NSBF should be contacted for specific information on weight restrictions, ballast weight, flight train rigging, and other factors that influence gondola design.

To supplement the discussion of gondola design, this recommendation includes information on materials and parts that have been used successfully in gondola construction.

1. Typical Gondola Environment

It is impractical to design the gondola to withstand all known flight hazards. The experimenter must identify the hazards which are likely to affect the payload and then address those hazards in the gondola's design. Thus, it is important for gondola designers to be familiar with the typical conditions to which a gondola is subjected before, during, and after flight.

1.1 Mechanical Environment

1.1.1 Pre-Launch

The gondola is usually assembled in one of the NSBF staging bays at the Palestine flight facility. Each work area is equipped with an electric hoist with which the gondola can be lifted. The various hoists have a lineal range up to 35 feet and have maximum lifting capacities from 3000 to 10,000 pounds. The gondola should be equipped so that it can be lifted in the staging area. It may also be useful to design a support structure with wheels for transporting the gondola for short distances without hanging it by the suspension system. At a remote launch site, a hoist may or may not be available for lifting and moving the gondola. In this situation, a mobile support frame or removable wheels are indispensable. (See Figure 1.)

The package is carried from the staging bay to the launch pad by the launch vehicle. It hangs from the vehicle by the launch pin, and on the trip to the pad, it can bounce with a force of up to 1/4 g. It is also subject to high frequency, low amplitude vibration from the vehicle's engine.

The ride to the launch pad is much less stressful than flight termination, so the components of the gondola that are designed to withstand flight conditions and termination will survive the ride to the pad easily. Rarely, a flight component that will withstand normal flight conditions is sensitive to the high frequency vibration of the launch vehicle. Also, experimenters often place devices on the gondola package which are removed before launch. These devices must be attached securely to the gondola during the ride to the pad.

1.1.2 Launch and Flight

The gondola experiences a jolt of about 0.5 g when the balloon is released and a similar shock when the gondola is released from the launch vehicle onto the ascending balloon train. These jolts rarely exceed 2 g.

During the ascent phase of flight, the gondola is commonly jolted by wind shears with up to 0.5 g of force. Structurally, a gondola that is properly designed to survive termination will withstand the stresses of ascent. However, problems may occur when high quality data collection is required during ascent. If data collection during ascent is critical to the experiment, these forces must be considered in the gondola's design.

The balloon may rotate as much as two revolutions per minute during ascent. To maintain accurate positioning, pointing systems must work harder during this phase of balloon flight than during any other. Furthermore, the inertia of a heavy payload may twist the flight train below the rotating balloon. To decouple the payload from the rotating flight train, the NSBF recommends that a swivel be included in the flight train of any gondola exceeding 3000 pounds.

The balloon system typically ascends at approximately 750 feet per minute. Thus, the gondola may spend as much as 3 hours in the ascent stage to reach an altitude of 130,000 feet.

Float is mechanically the lease stressful portion of the gondola's flight. The gondola altitude is fairly stable except for the variations that occur at sunrise and sunset. Balloon rotation is usually less than 1 rpm.

1.1.3 Termination and Descent

At termination, the gondola and parachute are separated from the balloon. As part of the flight train, the parachute is under tension during flight. The stored energy released at termination causes the parachute to recoil toward the payload. (See Figure 2.) The gondola falls for 4 to 6 seconds until parachute opening, when the gondola's fall is slowed with a deceleration of approximately 2 to 5 g.

The flight train may be misaligned during free-fall. In such cases, off-axis loading may occur in the suspension system. This problem is discussed in Section 3.1 Suspension Systems.

Forces affecting the gondola during the descent on the parachute are very similar to those discussed in the description of ascent. However, during descent, the gondola/parachute combination swings in a circular pattern at several rpm. Significant data loss usually occurs at termination and during descent due to antenna orientation. Experimenters concerned with good data transmission during descent should contact the NSBF about procedures for minimizing data loss.

1.1.4 Landing

The factors which affect the gondola most at landing are horizontal and vertical speed of the gondola and terrain at the impact site.

Typically, the gondola is traveling at approximately 15 knots vertically; horizontal wind speed at the impact site averages 10 knots but varies greatly. Higher wind speeds (15-20 knots) are often encountered on landings west of Palestine.

Impact conditions for flights originating in Palestine vary considerably, depending on the direction of flight. Summer (westward) flights often impact in West Texas where the gondola may land in hard, open ground; in gullies; or on rocks. There is also a slight chance that the gondola will land in a small body of water such as a farm pond.

Typical impact sites for spring or fall turnaround and winter (eastward) flights include open fields, densely wooded areas, swamps, and farm ponds. An open field is the most desirable site and is preferred for landing when possible. However, landings in trees or shallow water are not uncommon when flying over the southeastern United States. In wooded areas, the parachute or gondola may become entangled in branches, suspending the payload above the ground.

Upon impact, the tracking plane pilot releases the parachute from the gondola by radio command to prevent a reinflated parachute from dragging the payload. The pilot can only fire the parachute cutaway after sighting and verifying that the gondola is on the ground. For this reason, the parachute cutaway is almost never fired during nighttime terminations. When the parachute cannot be cut away after impact, it may reinflate and tip the gondola over. In extreme cases, the parachute may drag the gondola.

1 .1 .5 Recovery

Flights are terminated so that the gondolas will land in sparsely populated, rural areas. The recovery procedure varies depending on the actual impact location. For instance, although the NSBF uses specialized recovery vehicles, it is often impossible to reach payloads on a maintained road. Crews must often negotiate with landowners to enter private property or to cut roads into inaccessible spots. These conditions can delay recovery of the entire package from a few hours to a few days.

If the recovery process has been taken into consideration during the design stage, the gondola is less likely to incur damage during a difficult recovery. The gondola should be easy to disassemble using conventional tools. Sensitive detectors which are easily removable can be recovered quickly, even if the entire recovery process is lengthy.

Batteries must be easily accessible for removal by recovery crews because expended batteries and powered-up equipment pose fire hazards.

Gondolas are transported on open trailers, and the road trip from the impact site to the NSBF is often rough. The gondola typically experiences jolts of 5 to 7 g throughout the ride and unprotected equipment may return to the NSBF covered with dust.

1.2 Thermal Environment

There is little thermal stress on the gondola while in the staging area because work areas are heated or cooled as necessary. In the summertime, a cool gondola taken out to the flight line on a warm, humid day may be affected by condensation. This problem can be avoided by dry gas purging of critical enclosures or by warming the gondola before it leaves the work area.

Extreme temperatures on the flight line can affect thermally sensitive equipment in the gondola.

Summertime temperatures may reach 50°C a few inches above the launch pad, and temperatures at the gondola's height several feet above the pad may exceed 40°C. The gondola may also sit in direct sun during the flight line checkout period before launch, which can compound overheating problems. Extreme temperatures for Palestine are provided in the following table.

MONTHLY TEMPERATURE EXTREMES FOR PALESTINE AREA.

	Record High	Record Low	Mean
Jan	84◦F	-4◦F	48.4◦F
Feb	88	-65	2.3
Mar	95	14	58.1
Apr	95	30	66.2
May	97	39	72.9
Jun	103	48	80.0
Jul	114	57	82.5
Aug	110	56	83.1
Sep	108	42	77.7
Oct	101	27	69.0
Nov	87	17	57.5
Dec	82	8	50.8

On ascent, the gondola passes through the coldest layer from about 40,000 to 70,000 feet. For as much as 60 minutes, the gondola is exposed to temperatures below -60°C. Frozen condensation formed during ascent through the troposphere usually sublimates before the gondola reaches 70,000 feet. On descent, the gondola encounters the same thermal conditions for about 10 minutes. As external components cool during descent, water may condense and freeze on the gondola. Moisture accumulation usually begins below 50,000 feet on descent and may damage sensitive, unprotected components of the payload or may start corrosion if the gondola is not disassembled and cleaned soon after flight.

During daytime flights, the gondola has little protection against direct sun and marked temperature differences occur between shaded and unshaded areas.

The thermal flight environment presents a very complex design problem. Internal temperature is affected by insulation, outside surface color, the gondola's size, pressurization, heat produced by electronics, and braces which enhance heat transfer into and out of the gondola. Studies by Carlson et al (1, 2) examined the influence of these factors on the gondola, and a computer program for modeling a gondola's thermal properties was developed from this information (3). This computerized thermal modeling service is available to users through the NSBF.

Depending on the degree of thermal stability required for the payload to function properly, it may be necessary to manipulate the gondola's temperature through passive and/or active thermal control.

Passive controls such as painted surfaces and insulation adequately protect most control-type electronics that are designed for the balloon flight environment. Because the thermal behavior of a surface painted with a color of known absorptivitv/emissivity is more predictable than that of a bare metal surface, the gondola surface is often painted to control temperature. Insulation will typically maintain the internal temperature of electronics boxes within a range of -50 to +60°C. (See Appendix G for thermal properties of paint and insulation.)

When passive controls are inadequate, power equipment may require pressurization and in extreme cases may require active cooling. The most common active control device used on gondolas is the radiator. (See Figure 3.) Three types of radiator panels have been used successfully: passive heat transfer, electrical resistance, and fluid-filled.

Several fluids have been used in gondola radiators with varying success. Ethylene glycol/water mixtures freeze at high altitudes, however, fluorocarbon fluids developed as electronics coolants have been used successfully. A series of fluorocarbon fluids called Fluorinert Electronics Liquids are available through 3M Commercial Chemicals Devision. See the Fluorinert information publications available from 3M (St Paul, Minnesota) for the properties of these fluids.

The NSBF highly recommends that all electronics be thermally and vacuum checked to determine the limits of operation. A range of -50°C to +60°C up to 150K ft is sufficient in most cases. Environmental chambers are available at NSBF. However, they must be reserved with the Electronic Flight Operations Section Supervisor to avoid long delays when several scientific groups are preparing for flight. For maximum support, the use of environmental chambers should be scheduled during the off-season (usually from November through February and from mid-June through mid-August).

1.3 Electrical Environment

During package pickup and launch, the gondola hangs within 15 feet of the launch vehicle's motors (DC) and within 10 feet of the launch arm motor (AC). The vehicle usually runs during package pickup, the trip to the launch pad, and during the launch. The launch arm motor is only run during launch. The NSBF is not aware of any interference of these motors with electrically sensitive equipment, but they do create significant electrical fields.

2 GENERAL GONDOLA DESIGN

From experiences with successful and unsuccessful gondola designs, the NSBF has developed some specific design recommendations for critical parts of the gondola.

A typical gondola is a box-like or spherical framework equipped with a suspension system for attachment to the flight train. Surrounding the bottom and sides of the gondola is an impact absorption system which cushions the gondola on landing. The design of these structural elements is discussed in the following sections.

2.1 Weight and Size

In general, as experiments have become more complex, the weight of the average scientific package has increased. As a result, many gondolas are now pushing the upper weight limit of present safety regulations for balloon flight**.** Thus, gondola weight should be considered a resource to be utilized as efficiently as possible.

While the package must be sturdy enough to support equipment and withstand flight conditions, a balance must be maintained between structural integrity and gondola weight. To achieve this balance, some experimenters are now using design analysis computer programs and employing sophisticated construction techniques to minimize weight without sacrificing structural strength.

One of the critical elements of early design is the initial weight estimate. It is not uncommon for the gondola's final weight to be twice the original estimate. Therefore, the experimenter must carefully estimate the anticipated weight of all science instruments, science and NSBF electronics, and ballast. Further, the experimenter must build some flexibility into the design to accommodate added weight of experiment modifications. Changes in flight profile -- longer flight times, higher altitudes, and flights through sunset -also increase gondola weight by adding ballast weight.

The NSBF is capable of launching very large gondolas from its present equipment (See Appendix I.), but safety regulations governing the flight of payloads exceeding 3000 pounds may restrict such launches to remote sites or may influence the direction in which the gondola can be flown and its flight profile. For this reason, the experimenter should review the planned design and possible flight restrictions with the NSBF if projected gondola weight approaches 3000 pounds.

2.2 Modular Design

In the initial design stage, the experimenter should consider arranging the gondola in components, particularly if it is very large. A well-designed gondola arranged in components provides for experiment adaptation on subsequent flights without requiring redesign of the basic gondola structure. A gondola which can be broken down into smaller units is also easier to recover from inaccessible landing sites and to transport on field recovery vehicles.

2.3 Design for Field Recovery

The designer can avoid many field recovery problems by adopting a modular design and by limiting the size and weight of the gondola or of individual components. In general, the gondola should not exceed 8 ft in two dimensions and 20 ft in the third dimension. Entire gondolas or individual components not exceeding these dimensions can usually be loaded and transported on field recovery vehicles

The long dimension will probably be more restricted by the launch than by recovery capabilities and, depending on the suspension system's length, may be restricted to much less than 20 ft. Gondolas exceeding these dimensions require wide load permits which are difficult to obtain and which will delay return of the gondola to the NSBF.

The weight limits for recovery are no more restrictive than those for flight. However, lighter payloads are easier to recover.

Whenever possible, delicate instruments should be positioned within the gondola in such a way that they can be removed in the field and packed separately for transportation from the impact site to the NSBF. The experimenter should provide appropriate containers for packing components in the field. Any unprotected components will be exposed to weather and road conditions on the trip back to the NSBF.

Most recoveries will require a device to lift the payload onto the recovery trailer. There is no requirement for hoist points on the gondola. However, the designer may wish to provide and/or label hoist points to aid the recovery crew. (See Figure 1.)

The payload will be positioned on the recovery trailer in the most secure position, usually on its side.

2.4 Attachment Techniques

Most experimenters weld at least a portion of the gondola. However, welding should be used cautiously. As the proposed use of a material approaches the material's strength rating, the quality of a weld becomes more critical. In addition, heat-treated or work-hardened metals are weakened by welding. For instance, the strength rating of a material such as 6061 T6 aluminum is reduced from 32,000 psi to 12,000 psi by welding. This effect may reduce strength below design requirements.

Welds are usually difficult to evaluate for design analysis; therefore, the NSBF recommends bolting critical members of the suspension system and gondola framework. The preferred attachment technique is a bolted gusset plate. An advantage of bolting is that damaged members can be easily replaced without cutting and rewelding the structure. For internal structures designed to support equipment, the NSBF suggests the use of supports clamped to the gondola members. This technique also allows the internal arrangement of equipment to be reconfigured without reconstructing the entire gondola frame.

The NSBF gondola certification criteria require that all internal components remain contained (not necessarily intact) throughout flight and impact. However, to insure that delicate equipment is not extensively damaged upon impact, the designer may want to consider some sort of individual shock absorption system to protect internal components.

2.5 Balancing the Payload

The center of gravity (CG) will align directly under the suspension point when the gondola is lifted. Therefore, the location of the CG will determine the orientation of the gondola during flight. This principle allows instruments to be set at a predetermined angle. Any desired geometry (including level) must be carefully planned during the design stage.

The problem of payload balance must be addressed throughout the design and construction phases carried out at the experimenter's facility. After attaining the desired orientation, some degree of flexibility should be incorporated to allow line adjustments after pre-flight assembly. Some adjustment can be made by adding lead weights. However, deadweight is undesirable because it is a wasteful expenditure of gondola weight-carrying capacity.

The two most desirable ways of adjusting payload balance are by allowing adjustment of internal component location and/or providing for an adjustable suspension system. All adjustable components must be secured with locking devices for flight. Lock nuts and lock washers are acceptable for internal components, but when used in suspension systems, they should be supplemented with aircraft-type locking wires. Additionally, the amount of bolt length engaged after the final adjustment should be equivalent to 1-1/2 times the bolt.

The gondola should always be assembled and leveled at the experimenter's facility before arrival at the NSBF Failure to do so usually results in lost flight opportunities.

The ballast attachment should be configures so that ballast drops do not seriously affect gondola orientation. This can be accomplished by either 1) placing the ballast directly under the CG or 2) using multiple ballast hoppers positioned equidistantly from the CG. In the latter configuration, ballast must be discharged from al hoppers simultaneously in order to maintain balance. Thus, if the flow from any of the ballast hoppers in a multiple hopper arrangement is restricted during the flight, the gondola will become unbalanced. (See Section 3.3 for information on ballast hoppers and attachments.)

If the gondola must be level during flight, the CG must be maintained close to the geometric center of the gondola and directly under the suspension point. Otherwise, the suspension system members will be unevenly loaded. One principle axis radiating from the CG should pass through or near the suspension point to help stabilize the gondola during rotation and at flight termination.

3. DESIGN OF CRITICAL GONDOLA STRUCTURES

3.1 Suspension System

A typical gondola suspension system includes a suspension point which attaches the gondola to the NSBF flight train. The suspension point is, in turn, attached to the gondola by an arrangement of support members.

The gondola is usually suspended from the flight train by an eyebolt or pear-ring at the top of the gondola suspension system. The NSBF usually places a clevis in this eye to attach the gondola to the load train. (See Figure 5.)

The suspension members may be one of two types – flexible or rigid. In general, the NSBF does not recommend flexible systems for payloads over 3500 pounds and prefers rigid member systems even for lighter payloads.

3.1.1 Flexible Suspension Systems

A flexible suspension system is usually made up of cables or, less commonly, nylon webbing. A common design error is to use a flexible member but to restrict its movements at the attachment point with the gondola frame. At termination, the parachute recoils toward the payload causing the suspension system to go slack. If the member twists, it is possible that when the falling payload is jolted by the parachute opening the attachment device will be damaged by abnormal loading. A properly designed flexible suspension system should permit the flexible member to rotate fully around the attachment pont without binding. Also, each flexible member should be capable of supporting the entire payload in case one or more members fall.

The NSBF recommends using aircraft cable for flexible suspension systems rather than stainless steel. Stainless steel cables offer on particular advantages for balloon flight, and are more expensive to replace.

As noted above, a flexible suspension system will recoil into the payload at flight termination. Any rotator or swivel and even the launch fitting may impact the top of the gondola. Provisions should be made to protect delicate instruments that may be damaged by such an impact.

3.1.2 Rigid Suspension Systems

Most problems encountered in the design of rigid suspension systems stem from the difficulty of analyzing bending loads in a fixed beam. It is possible to design a strong, adjustable suspension system that induces no bending loads at either end of the main members.

One successful solution to this design problem places ball joints between the rigid member and the attachment points at each end. This type of member reduces bending loads by rotating at the joints. Several types of joints exist for this application. Joints with grease fittings should not be used because the tap for the fitting weakens the joint. (See Figure 6.)

3.2 Gondola Frame

The gondola frame is usually a box-like structure which contains science detectors and electronics. It must be capable of supporting this equipment and ballast.

One of the most important elements in frame design is the method of attaching members and supporting structures: welding, bolting, or clamping. These techniques were discussed in Section 2 General Gondola Design.

The framework may be open or can be covered by walls. Walls are seldom used as structural members, but often serve to protect internal components from direct sun during flight and to protect instruments from dust, rocks, and tree limbs upon landing. Depending on their construction, walls may also provide thermal insulation.

Of course, there are many variations on this basic pattern. As long as the gondola can be launched and recovered by the NSBF, is within the weight restrictions, and meets the NSBF certification requirements, the experimenter has great freedom in designing the actual gondola body.

As an alternative to the box-shaped structure, experiments are sometimes packaged as spheres. Such a gondola often contains a pressure vessel which may or may not be a structural member.

A common method of accommodating a pressure vessel is to build a supporting cradle within the gondola. The pressure vessel can also be bolted to an encircling flange which is, in turn, attached to the gondola frame.

The pressure vessel is more likely to survive flight and impact without damage if it is not a structural member. In addition, the design is easier to analyze for NSBF certification if the vessel is not a structural member.

3.3 Ballast Attachment and Hoppers

The NSBF provides hoppers and rigging for carrying ballast below the gondola. In a typical arrangement, the hoppers are supported by flat, nylon straps that attach to eyebolts. (See Figure 7.) The eyebolt is then inserted in a hole in a gondola member.

The NSBF provides AN-45 eyebolts for suspension of the ballast hopper straps, and usually drills holes for the bolts after the payload arrives at the NSBF. Four or more eyebolts are required for one or two hoppers. The scientist must identify the payload's center of gravity for proper position ing of the ballast hoppers and insure that the supporting members are capable of supporting 500 pounds of ballast with 10 g loading.

The scientist may provide ballast hoppers to replace the standard hopper used by the NSBF. Custom hoppers may be side-mounted or may allow special ballast handling that would otherwise be impossible. (See Figure 8.) The NSBF should be contacted for information on hopper design and ballast valves if the scientist intends to construct custom hoppers.

In designing the ballast attachment, the experimenter must anticipate the maximum ballast weight to be carried by the gondola and should be aware that factors such as increasing float altitude or flight time and floating through sunsets will increase ballast weight. Ballast requirements are based on the gross weight of the system: balloon, rigging, gondola, and ballast. More ballast is required for an evening or night ascent than a morning or daytime ascent. Increasing the float altitude requires a larger, heavier balloon and increased ballast for all phases of the flight. Extended turnaround flights may easily require in excess of 1000 pounds of ballast.

Refer to Section 2.5 for a discussion of the ballast hopper's effect on gondola balance.

3.4 Impact Attenuation System

A properly designed impact attenuation system must absorb the kinetic energy of the gondola in order to minimize damage to the gondola body and its internal components. The gondola motion must be considered as two components: horizontal velocity and vertical velocity. Typical impacts are planned not to exceed 25 fps vertical velocity. It is impossible to plan the horizontal velocity because it is determined by the prevailing winds at the impact site. However, 0 to 15 knots (0 to 25 fps) would be typical. The designer must decide how much cushion to provide and what perils (tree branches, large rocks, water, mud) to guard against. The impact attenuation system should at least protect the instrumentation from a vertical velocity of 25 fps.

A horizontal velocity will most likely cause the gondola to tip and possibly be dragged a short distance by the parachute. Therefore, protection should be provided for an unhampered tip-over.

The possibilities for additional protection are almost limitless and the designer and principle investigator must balance the interacting factors of weight, cost, and effective protection against the level of risk.

3.4.1 Non-reusable Systems

Most systems use paper crush pad or a similar material to absorb gondola kinetic energy at impact. Crush pad is attached to the bottoms and sides of most gondolas. The bottom layers absorb the vertical energy, while the layers on the sides protect the gondola in case of tipover. (See Figure 9.)

Crush pad can be attached in a number of ways. It should be easilv fastened to the gondola and easily replaced after flicjr,t. One successful technique is to glue the crush pad to plyboard which is then bolted to the gondola. After flight, the member is simply unbolted from the gondola for replacement before the next flight.

It is imperative that the designer make calculations to determine an effective crush pad design. The crush pad must begin crushing under the weight of impact and crush at a rate that dissipates the energy of impact before the material bottoms out. If an arbitrary configuration is attached to a gondola, it is possible for the gondola to destroy itself upon impact, leaving the crush pad undamaged. (See Appendix H for a sample calculation of crush pad requirements.)

An inverted pyramid of crush pad has proven to be very successful. Lower layers of the pyramid crush quickly. The payload's descent into the crush pad is then slowed as the layers with greater surface area (and therefore greater crush resistance) are expended.

The NSBF stocks one type of crush pad for use by scientists. This material is described in Section 4.3 Crush Pad.

Other types of disposable systems can be used instead of crush pad. They are usually composed of crushable members such as large diameter, thin-walled aluminum pipe that collapses on impact. These members usually bolt onto the gondola so that they can be replaced after flight.

3.4.2 Reusable Impact Attenuation Systems

A few gondolas have been constructed with reusable impact systems. Most of these systems use shock absorbers which survive impact without being permanently deformed. Consequently, they do not have to be replaced after each flight. This type of system is used infrequently and, unless carefully designed, it is often unsuccessful at either surviving impact or adequately protecting the payload.

Such a system is typically more difficult to design than a disposable system. However, over the span of several flights a reusable system may save replacement and design time as well as material expenses.

Like disposable systems, reusable impact systems must be able to absorb horizontal and vertical energy and provide protection in the event of tipover. Therefore, some shock-absorbing members must be positioned on the sides or upper edges of the gondola. (See Figure 9.)

4. MATERIALS

4.1 Metals

The NSBF recommends 6061 T6 aluminum for gondola construction unless another metal is known to have advantages for a particular application. The 6061 T6 alloy is weldable and workable and it does not become brittle at typical temperatures encountered during balloon flight. Some of the exotic aluminum aircraft alloys do not perform so predictably.

If there is a doubt s to a metal's suitability, refer to the Mil 5 Handbook. The Mil 5 Handbook (latest edition) will be used by the NSBF in checking stress analysis calculations.

4.2 Insulation

Two types of foam insulation are typically used in ballooning – ethafoam (white) and styrofoam (blue). The insulating values for these foams are listed in Appendix E. White foam is a better insulator but it will be dimensionally deformed after a balloon flight and may have to be replaced. The blue foam is dimensionally stable and is generally preferred for insulating components such as electronics boxes.

4.3 Crush Pad

The crush pad stocked by the NSBF is a paper honeycomb product (KF-1-80(0)EDF 51 lb) manufactured by International Honeycomb Corp. (Park Forest South, Illinois). It is supplied in 4' x 5' sheets 4 inches thick with 1-inch cell size. Each sheet weighs 5 pounds, and approximate crush strength si 10 psi.

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